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— PROVIDING GLOBAL SOUTH CLEAN ENERGY INSIGHTS —

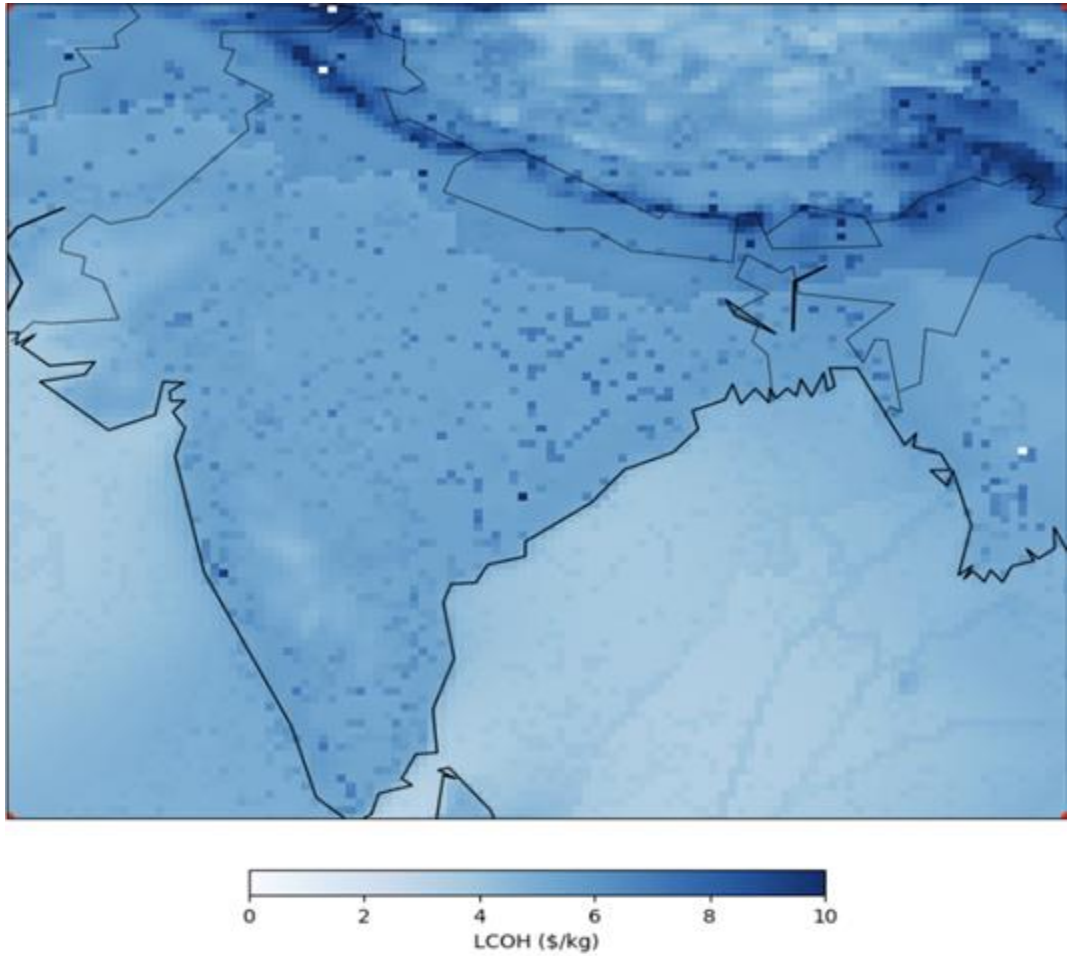
Power-to-Liquid Sustainable Aviation Fuels (SAF) as a Catalyst for India's Green Hydrogen Economy

***Prepared For*: Various U.S.-based Organizations**

India’s Green Hydrogen Landscape

- Current Indian (lower bound) green hydrogen costs range between **$5.00 - $6.00** per kg (barring subsidy)
  - Costs are ***3 – 4x higher*** than current blue and gray production costs
- India has outlaid **$2.1 billion across:**
  - Electrolyzer manufacturing
  - Direct H2/H2 derivative subsidies
- Analysis indicates that this funding alone is not enough to reach cost parity:
  - Costs remain **2 – 3x more expensive**
  - Subsidies are significantly less than U.S./E.U. producers

India’s Green Hydrogen Costs



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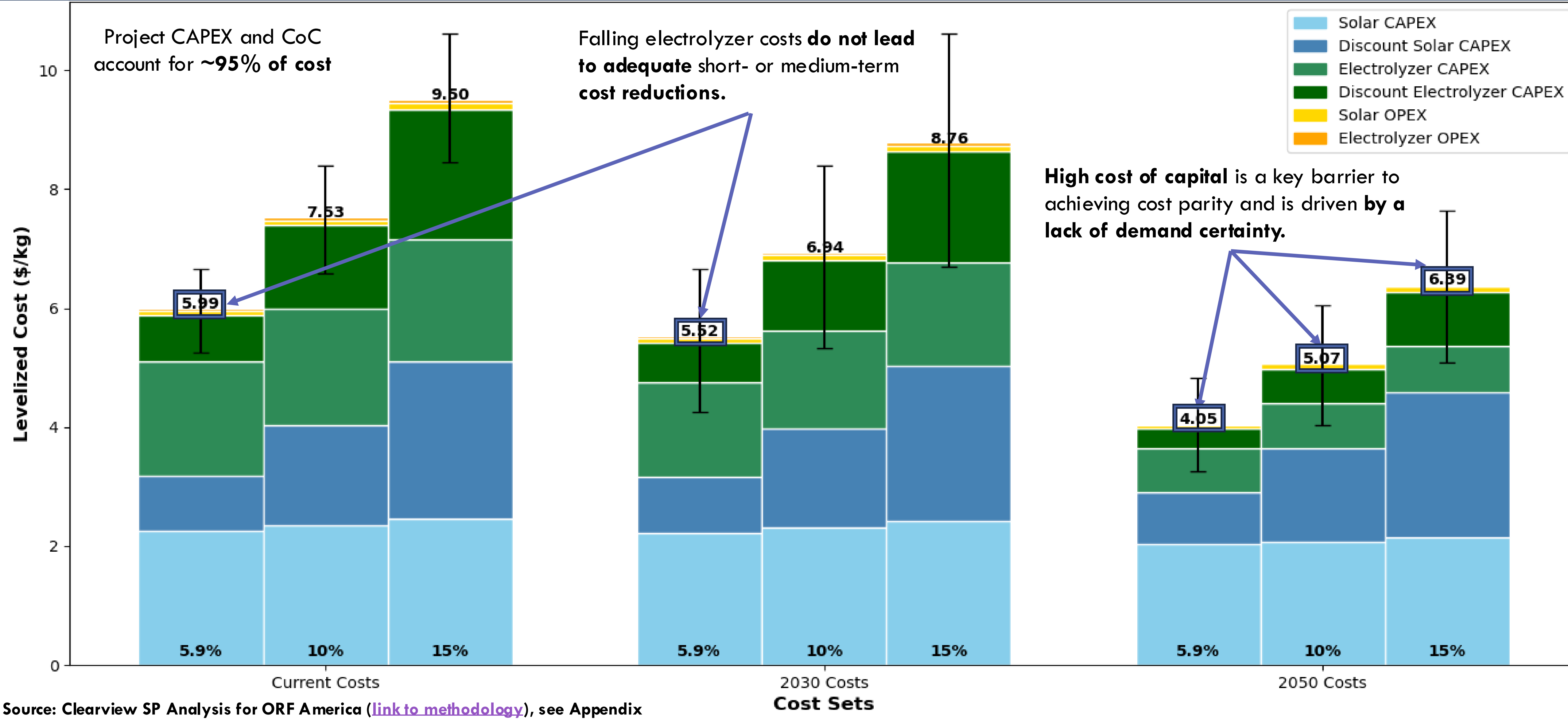
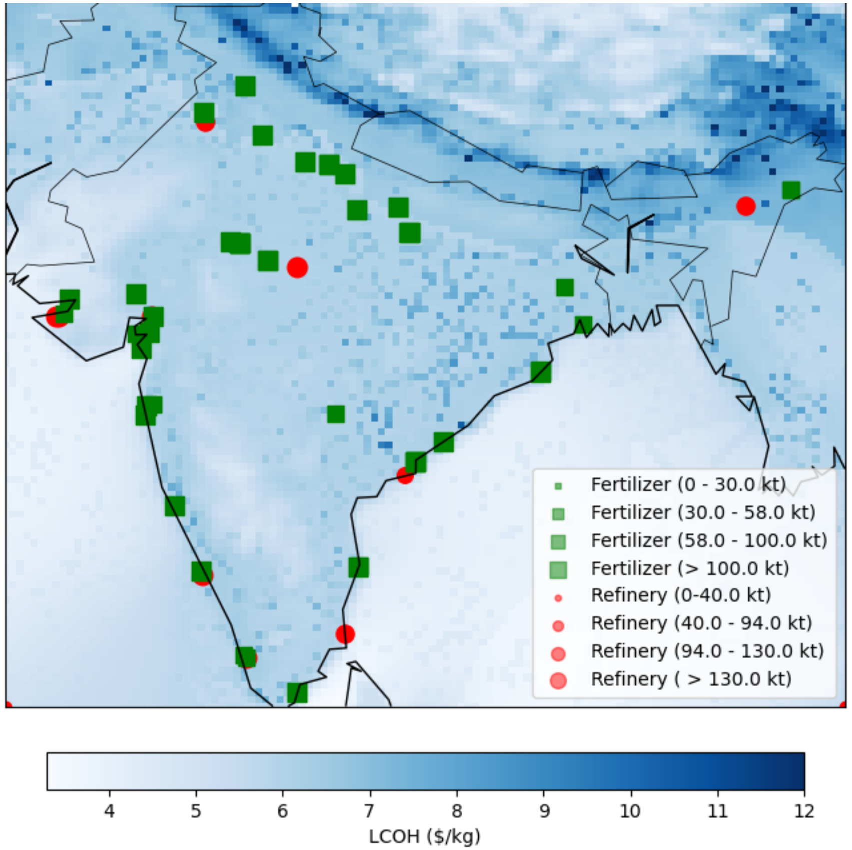
Source: Clearview SP Analysis for ORF America ([link to methodology]), see Appendix

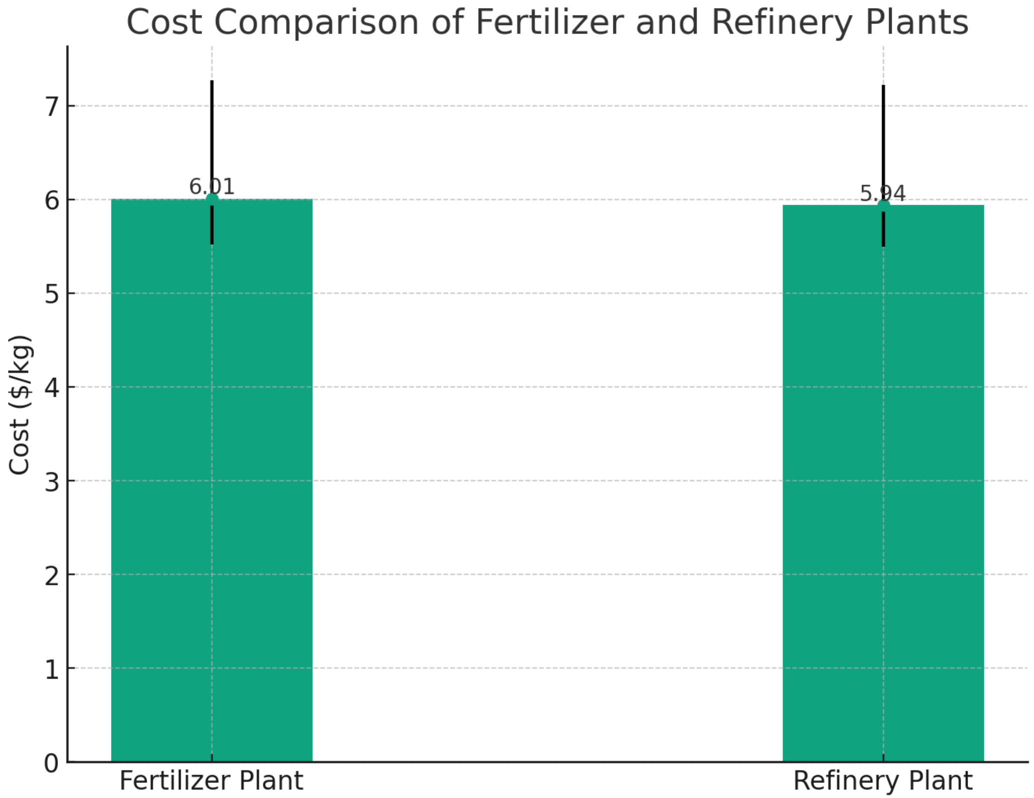
Reaching Green – Gray Cost Parity Will Require Lower Costs of Capital



Source: Clearview SP Analysis for ORF America (link to methodology), see Appendix

Fertilizer and Refineries Face High Green Hydrogen Production Costs





- Production costs range from $5.21 → $7.27 per kg of H2.
- The cost at the cheapest fertilizer/refinery plant **is more than 2.8 times** as expensive as grey hydrogen; at the most expensive plants, green hydrogen **costs are nearly 3.8 times as expensive.**

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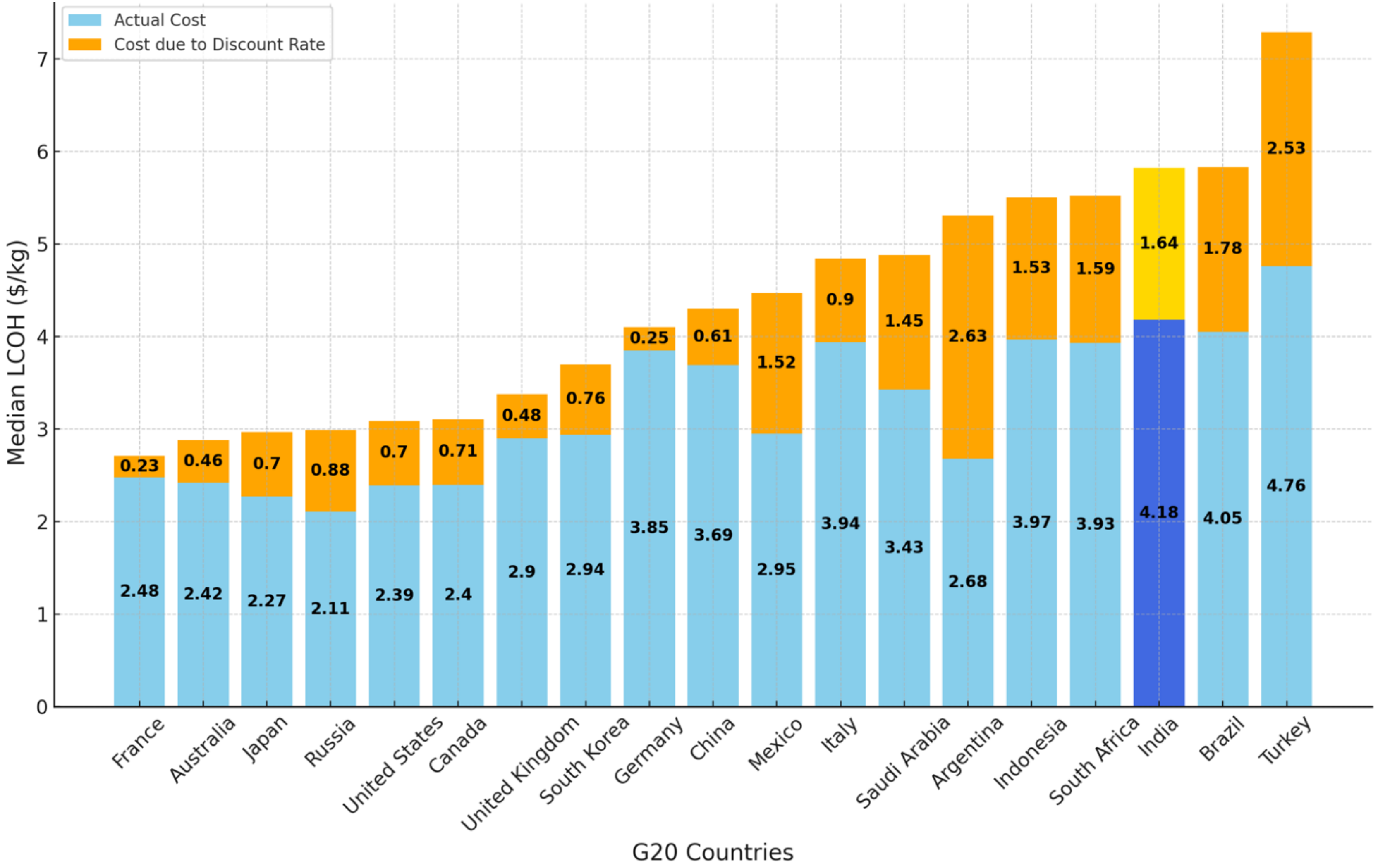
Source: Clearview SP Analysis for ORF America ([link to methodology]), see Appendix

India Green Hydrogen Costs Rank as "Middle of the Pack" In the G20



- To compete as a global exporter, India needs to:
  - Reduce median **production costs by 53%.**
  - Lower minimum **production costs by 48%.**
- For cost advantage over G20 importers:
  - Median **production costs must decrease by ~30%.**
  - Minimum **production costs should be cut by ~25%.**

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Source: Clearview SP Analysis for ORF America (link to methodology), see Appendix

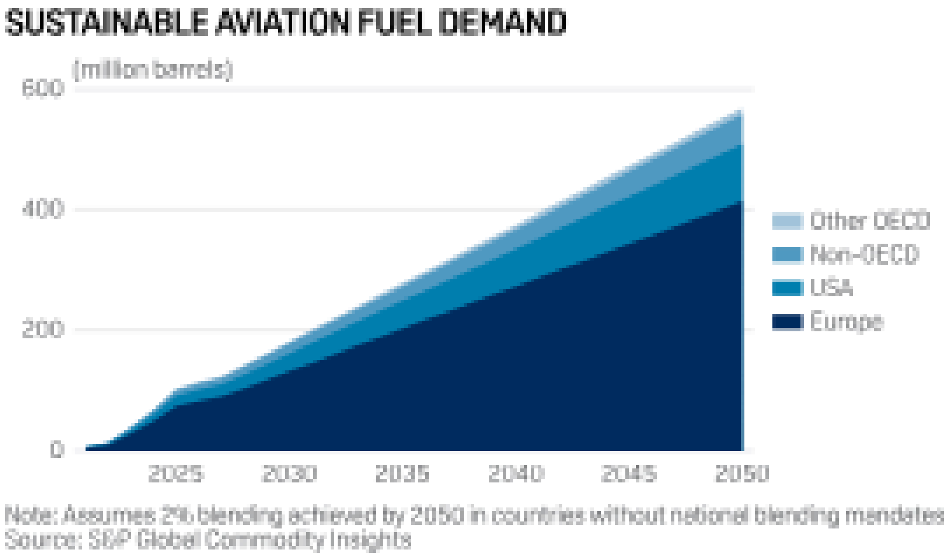
Building a GH2 Ecosystem Requires Sectors With Proven Demand and High W2P

- Sustainable aviation fuels (SAF), driven by global, domestic, and airline-specific decarbonization mandates have:
  - Necessary hydrogen demand
  - A willingness to absorb a green premium
- India is considering a SAF mandate of between 1 – 5 % by 2027[1].
- The EU has a 2% SAF mandate by 2025, 6% by 2030, and 63% by 2050[2].

1. https://www.mycwt.com/news/blog/fueling-change-saf-takes-flight-in-business-travel-sustainability/
2. https://www.easa.europa.eu/eco/eaer/topics/sustainable-aviation-fuels

Demand for SAF is High, Even With Increased Production Costs

- SAF demand has outpaced production[1]:
  - In 2024, SAF **demand was 2.156 million mt** and **supply was 2.13 million barrels.**
  - "Every drop of SAF produced has been bought", despite prices being more than **2 times more expensive** than current jet fuels.



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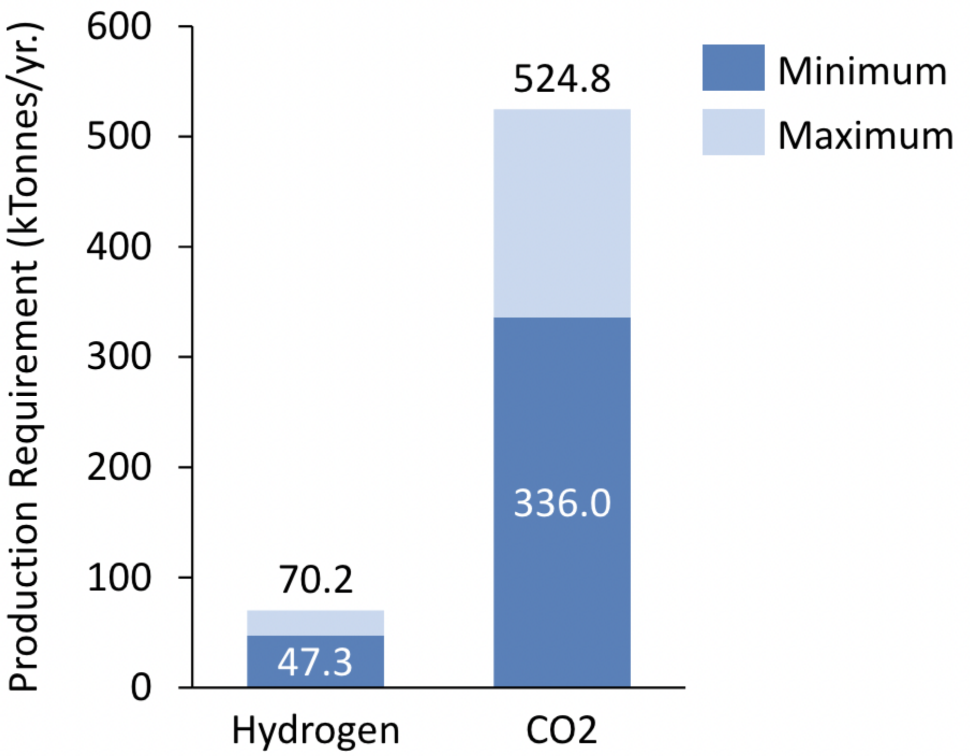
1. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/120623-saf-production-to-triple-to-15-mil-mt-in-2024-but-progress-slow-iata

SAF Pathways Require Green Hydrogen And Could Act as a Long-term Offtaker

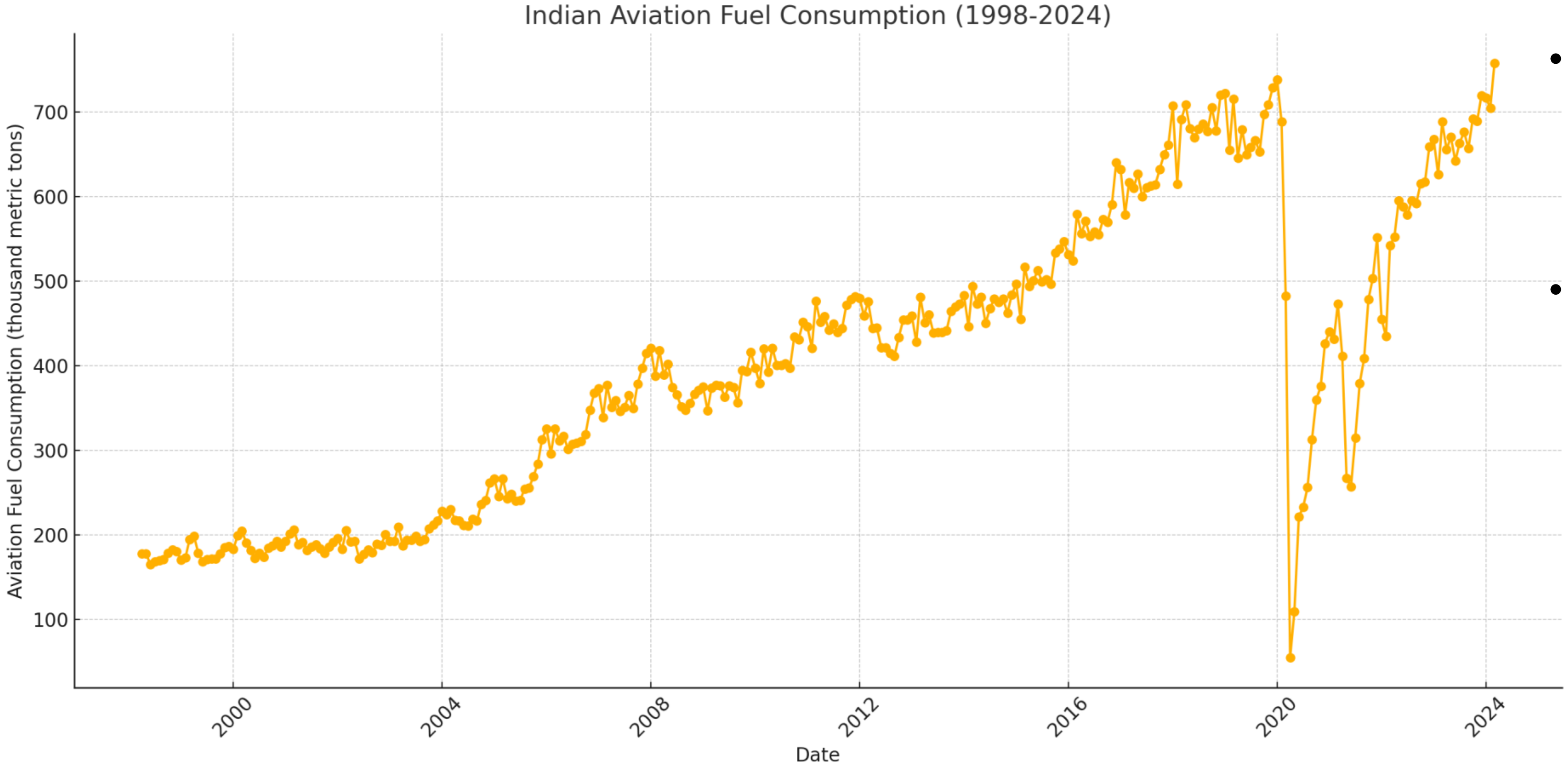
- Power – to – Liquid (PtL) SAF production requires electrolytic hydrogen and point source/captured CO2.
    - Green hydrogen is required to meet this demand.
- Biofuel-based SAF has a higher TRL, but questionable decarbonization effects and is unsustainable.

Hydrogen and CO2 Required to Replace 0.7% of 2030 UK SAF Demand[1]



1. https://www.transportenvironment.org/uploads/files/H2-use-in-aviation-EE_TE-Update-Nov22.pdf

Indian Fuel Consumption is Growing, PtL SAF is Required to Achieve Decarbonization Goals



- Bio-based SAF could provide up to 24 million tons of feedstock
  - Meet 1% SAF targets by 2030
- PtL SAF will be required to meet demand by 2050
  - Sell into global markets
  - Achieve complete decarbonization

Source: Clearview Analysis; Data aggregated from Petroleum Planning and Analysis Cell

PtL SAF Supply Chain Components

1. Feedstock Production

Hydrogen Generation

Renewable Energy → Electrolysis

CO2 Collection

Point Source Capture
DAC

2. SAF Production, Transportation, and Blending

Synthesis Facility → Trader/Storage → SAF Plant → SAF Blend Point →

3. SAF Use

SAF Fueling and Use

Required Plant Components

PtL SAF Locations Require:

1. **CO2 Source**
   1. Point Source
2. **Hydrogen Source**
   1. Electrolytic
   2. Carbon Capture
3. **Intermediate Transportation**
4. **Appropriate Demand Profiles**

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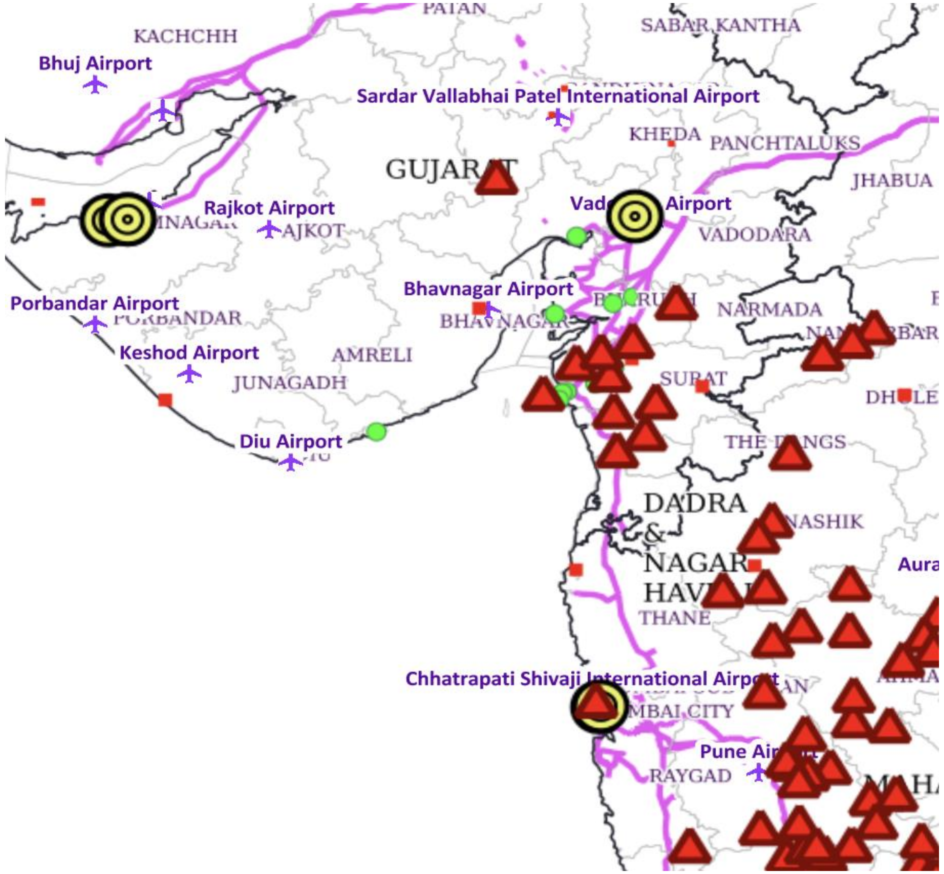
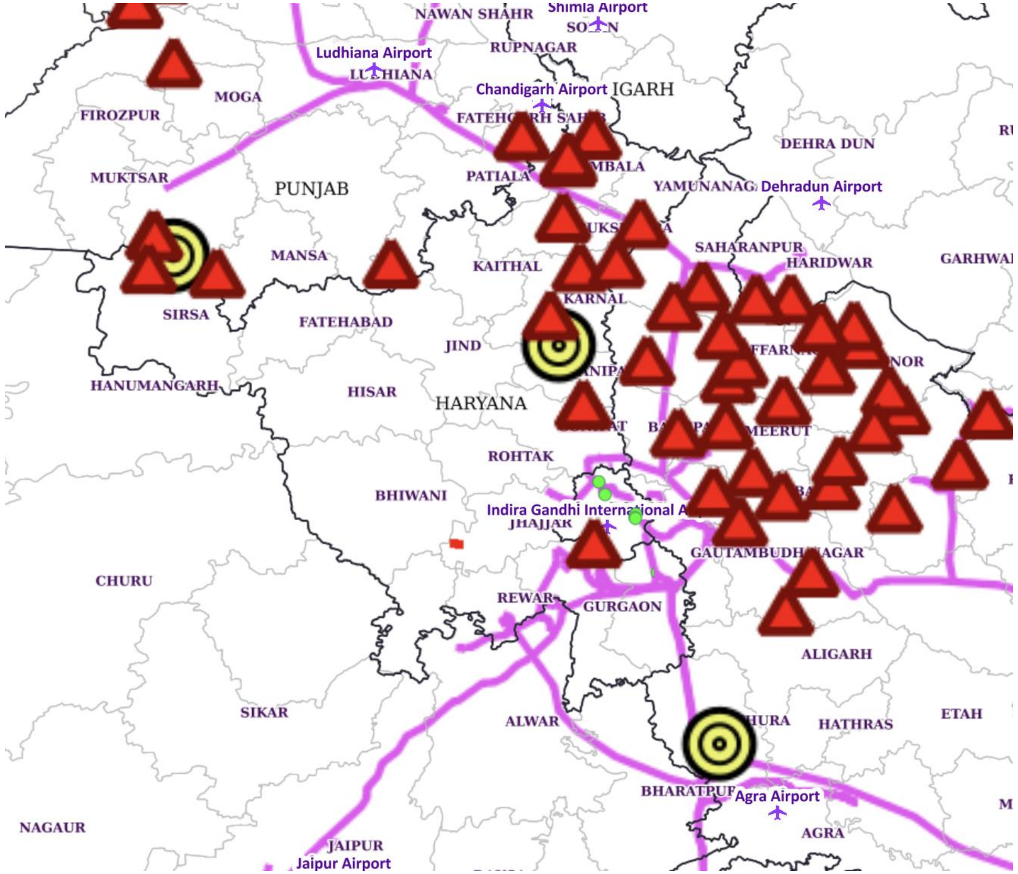
Regions in India Have High PtL SAF Potential and Warrant A Deeper Dive

Gujarat/Maharashtra



Haryana/Uttar Pradesh



Legend

- Ethanol Plants
- Refinery
- Airport
- Petroleum Pipeline

- Ethanol plants and refineries represent potential sources of CO_2 capture

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Source: NITI Aayog

Example Analysis: Generating FT Fuels Using Green Hydrogen and Captured CO2

- To evaluate India's (and other country's) PtL SAF potential, Clearview has built a techno-economic cost model to:
  - Estimate current production costs
  - Identify key cost drivers
  - Evaluate the effect of tax credits and policy incentives
- Power-to-Liquid SAF production is an expensive endeavor but provides real emissions reduction benefits.
- The following slides provide an example analysis to highlight the potential uses for this model.

Individual Component Models for Feedstock Production

1. Hydrogen Production

Renewable Energy

Electrolysis

Financial Inputs

Levelized Cost of Hydrogen Production

- Cost breakdown
- Sensitivity analysis
- Uncertainty analysis

2. Cost of Captured Carbon

Point Source CO2 Emissions

Natural Gas Cost

Transportation Cost

Financial Inputs

Cost of Captured CO2

- Analyze various point sources:
  - Ammonia
  - Ethanol
  - Coal
  - Etc.
- Cost breakdown
- Sensitivity analysis
- Uncertainty analysis

3. PtL FT Model

Hydrogen Cost

Carbon Dioxide Cost

FT + SAF Synthesis

Financial Inputs

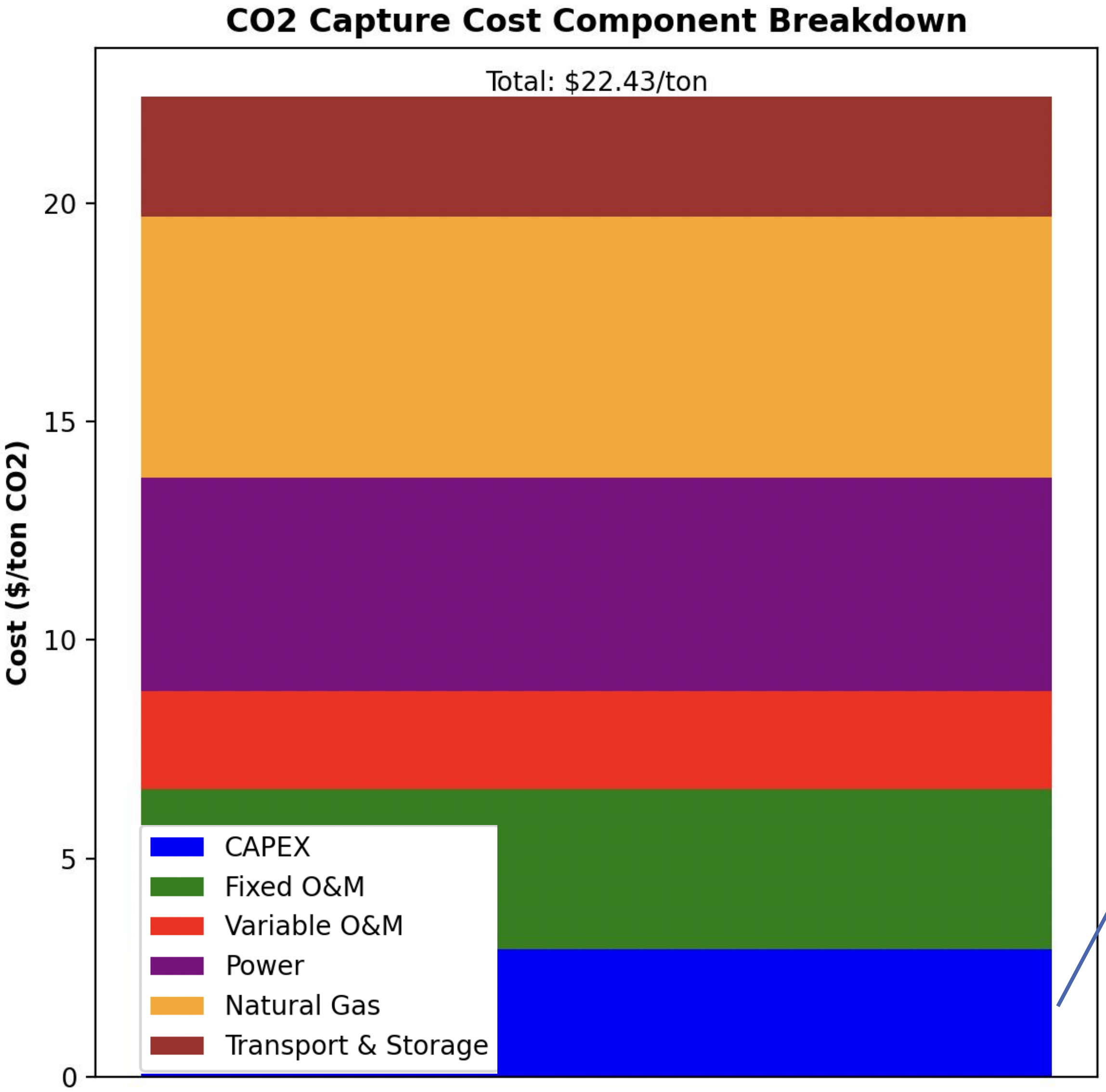
Minimum Fuel Sales Price

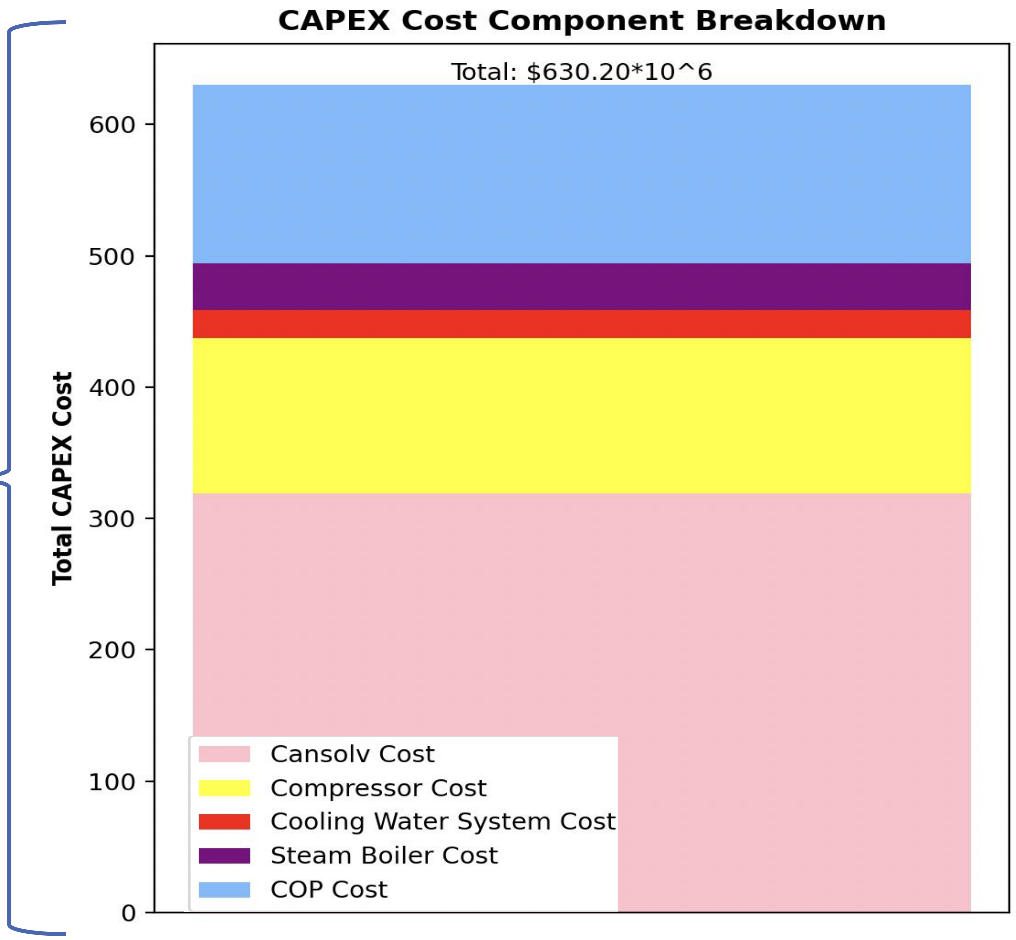
- FT synthesis
- RWGS
- Cost breakdown
- Sensitivity analysis
- Uncertainty analysis

CO2 Capture Model Parameters

Parameter	Value
Purchased Power Price ($/MWh)	58.5
Purchased NG Price ($/MMBTU)	6.3
Capital Charge Factor	5.5%
Fraction of Total Available CO2 in Primary Reformer	34% (18% CO2 by volume, low purity)
Fraction of Total Available CO2 in Stripper Vent	66% (99% CO2 by volume, high purity)
CO2 Transportation and Storage Costs ($/ton)	10
Plant Lifetime (years)	30

CO2 Capture Model (Cost Breakdown)





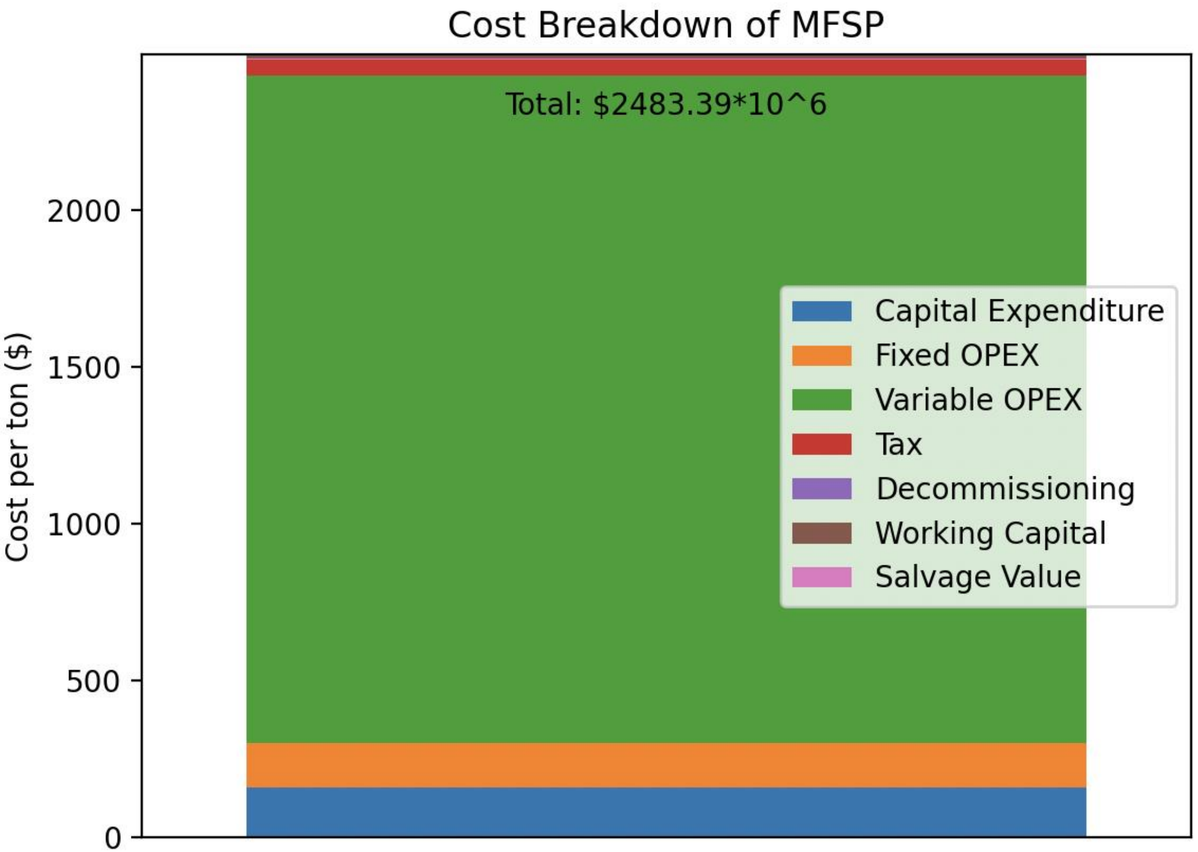
Each cost component can be broken down into sub-costs in order to identify cost linkages and appropriately model potential finance/policy effects.

Source: Clearview SP Analysis

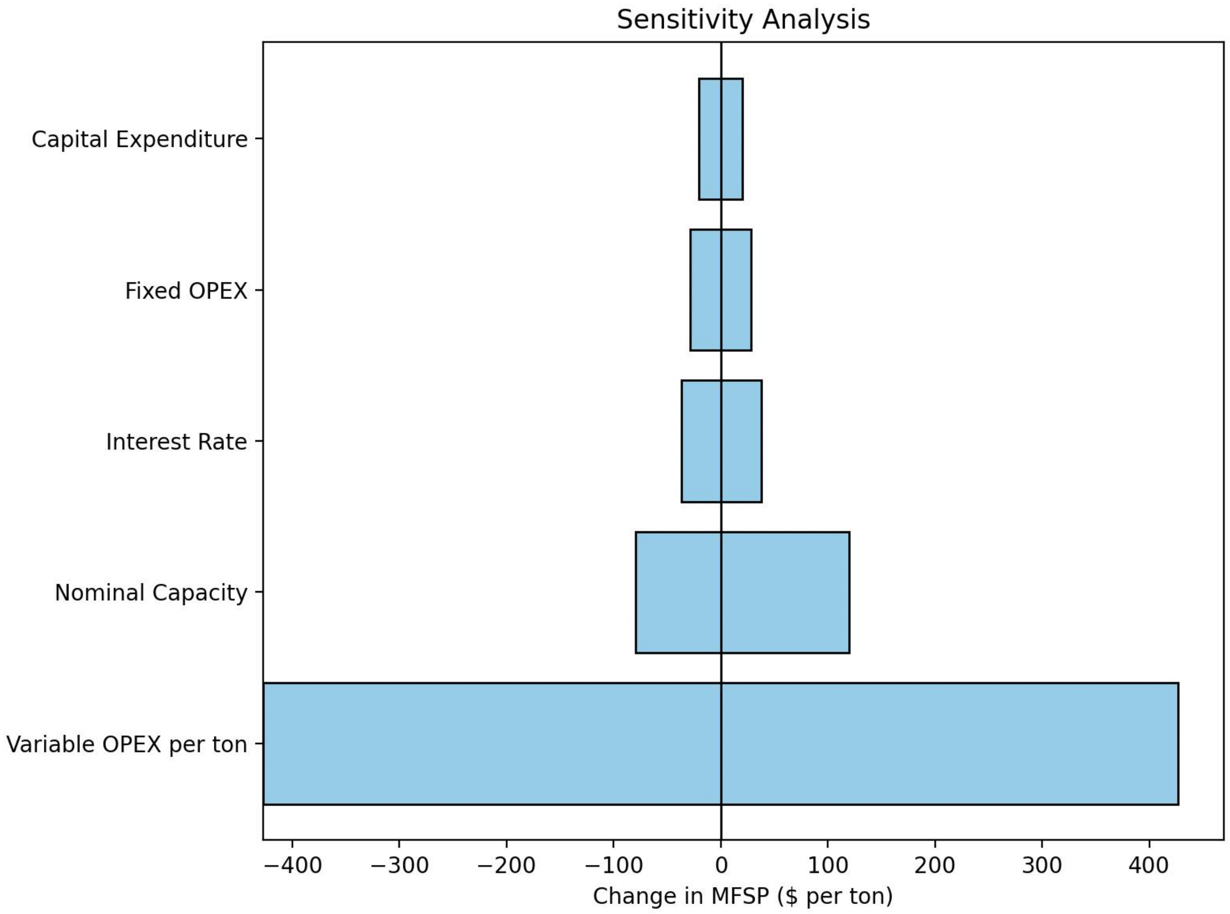
PtL Fischer-Tropsch Model Parameters

Parameter	Value
Nominal Capacity (tons/year)	~128,000
Construction Period (years)	3
Plant Lifetime (years)	40
Depreciation Schedule (type, years)	MACRS, 20
Interest Rate	3.7%
Decommissioning Costs	10%
Total Tax Rate	25.74%
Green Hydrogen Cost ($/kg)	6.00

PtL FT SAF Model (Cost Breakdown)



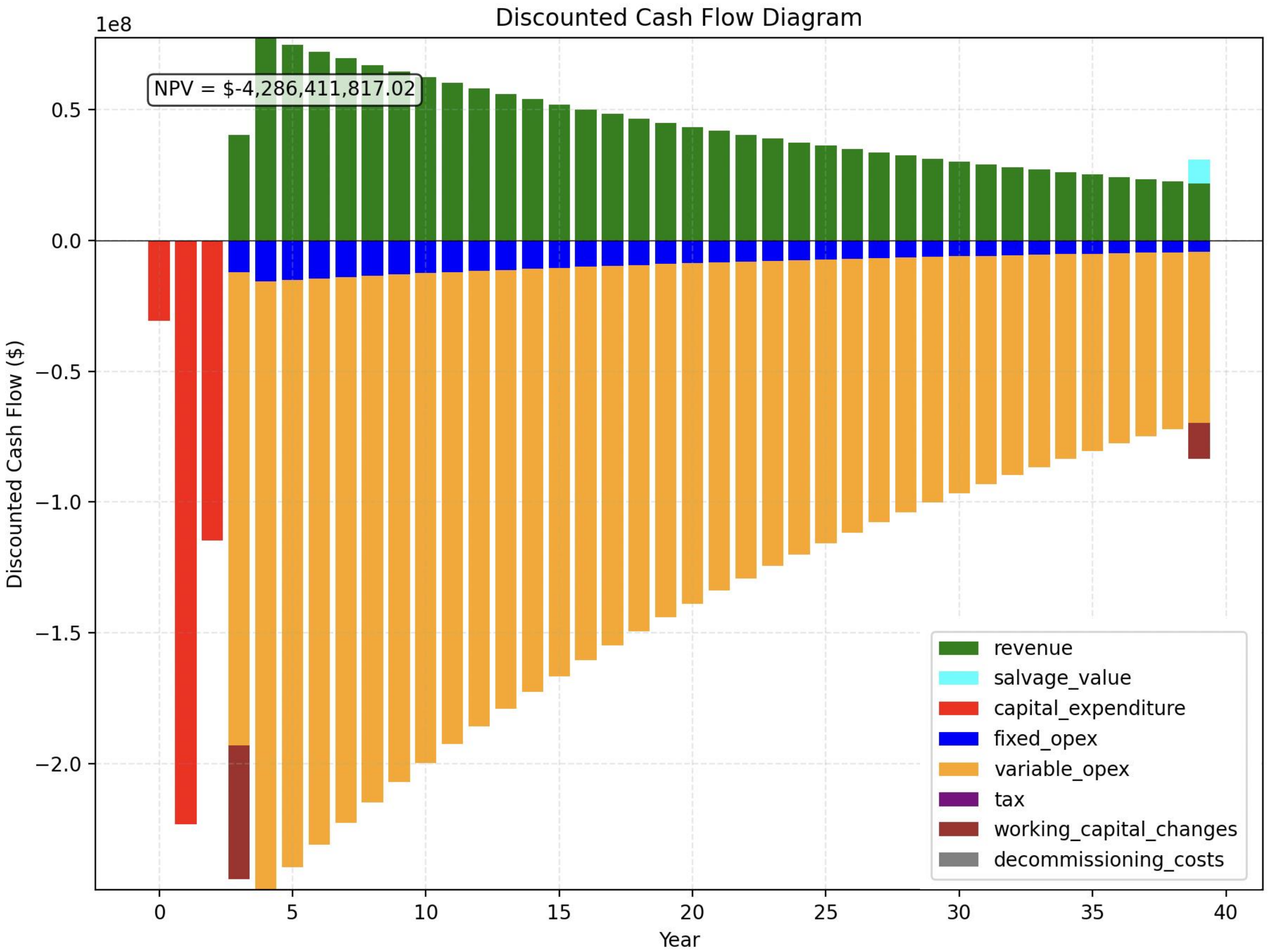
Cost breakdown of the Minimum Fuel Sales Price. Variable OPEX (i.e. feedstock costs), are responsible for >80% of total costs.



Variable OPEX (feedstock costs) are key driver in creating cost decline. Reducing feedstock costs by 20% results in MFSP falling by over $400.

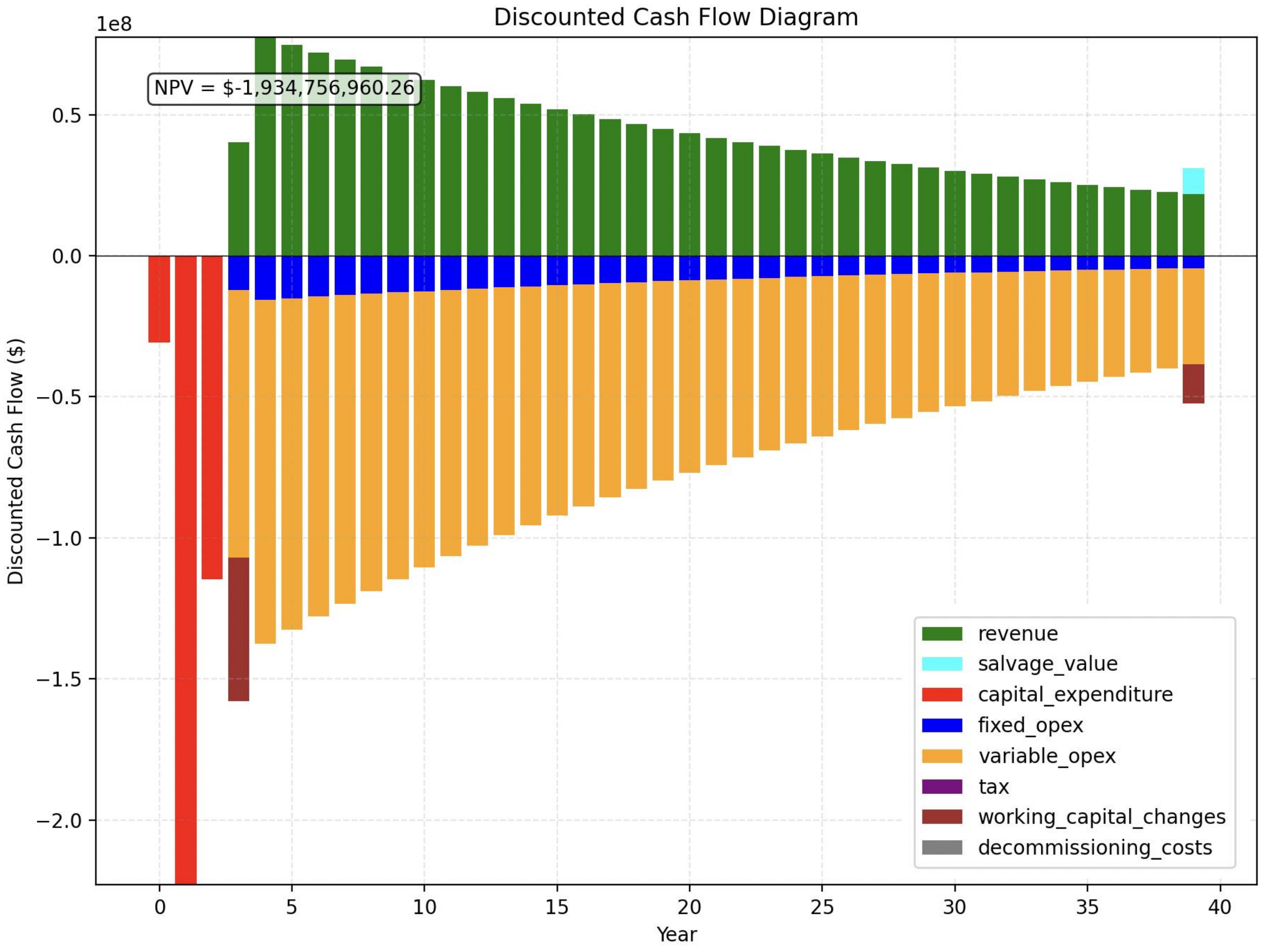
Source: Clearview SP Analysis

At current jet fuel market prices, a PtL SAF project fails to reach bankability.



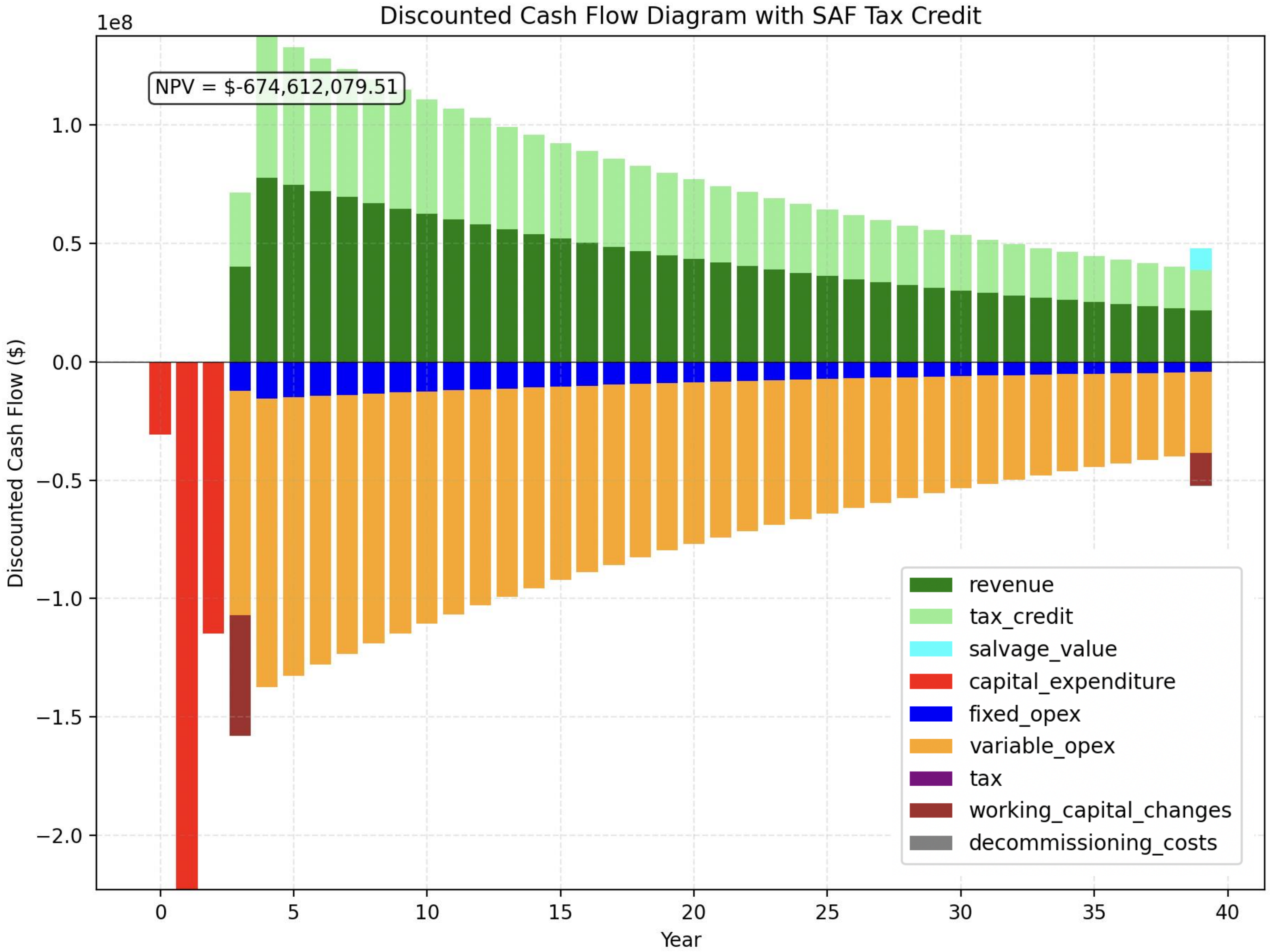
- Selling PtL SAF at market price results in **NPV of ~ -$4 Billion**
  - Market price: **~$700/ton**
  - Green hydrogen costs is the primary cost driver.
  - A cost reduction is necessary to achieve positive NPV

Reduced GH2 costs improve NPV but fail to achieve breakeven costs



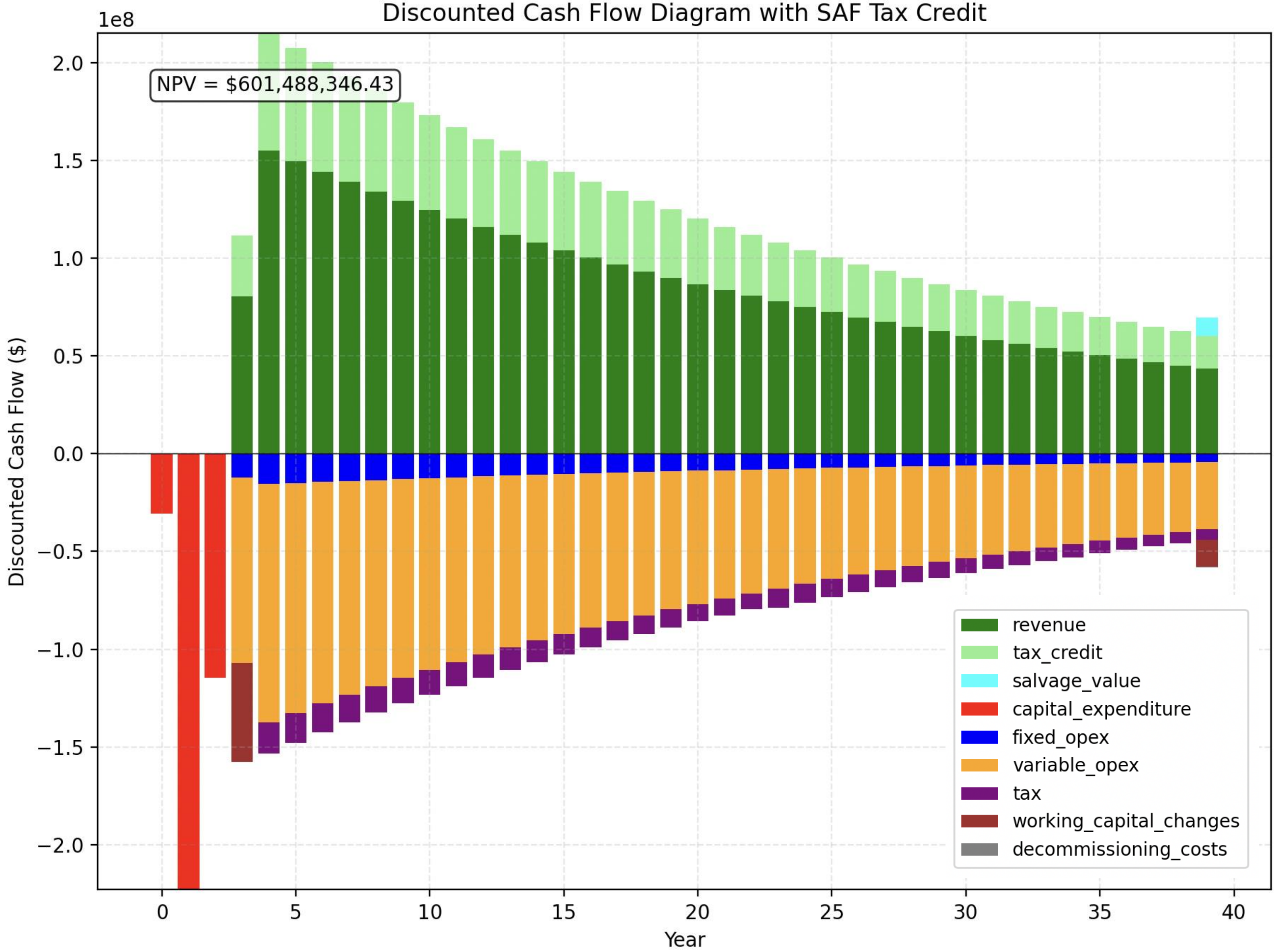
- Reducing green hydrogen costs from $6.00 to $3.00 per kg, approximately halves project NPV to - $2 billion.
  - **Achieving cost parity requires additional revenue support.**

U.S. 40B SAF tax credit and reduced GH2 costs fail to reach breakeven NPV.



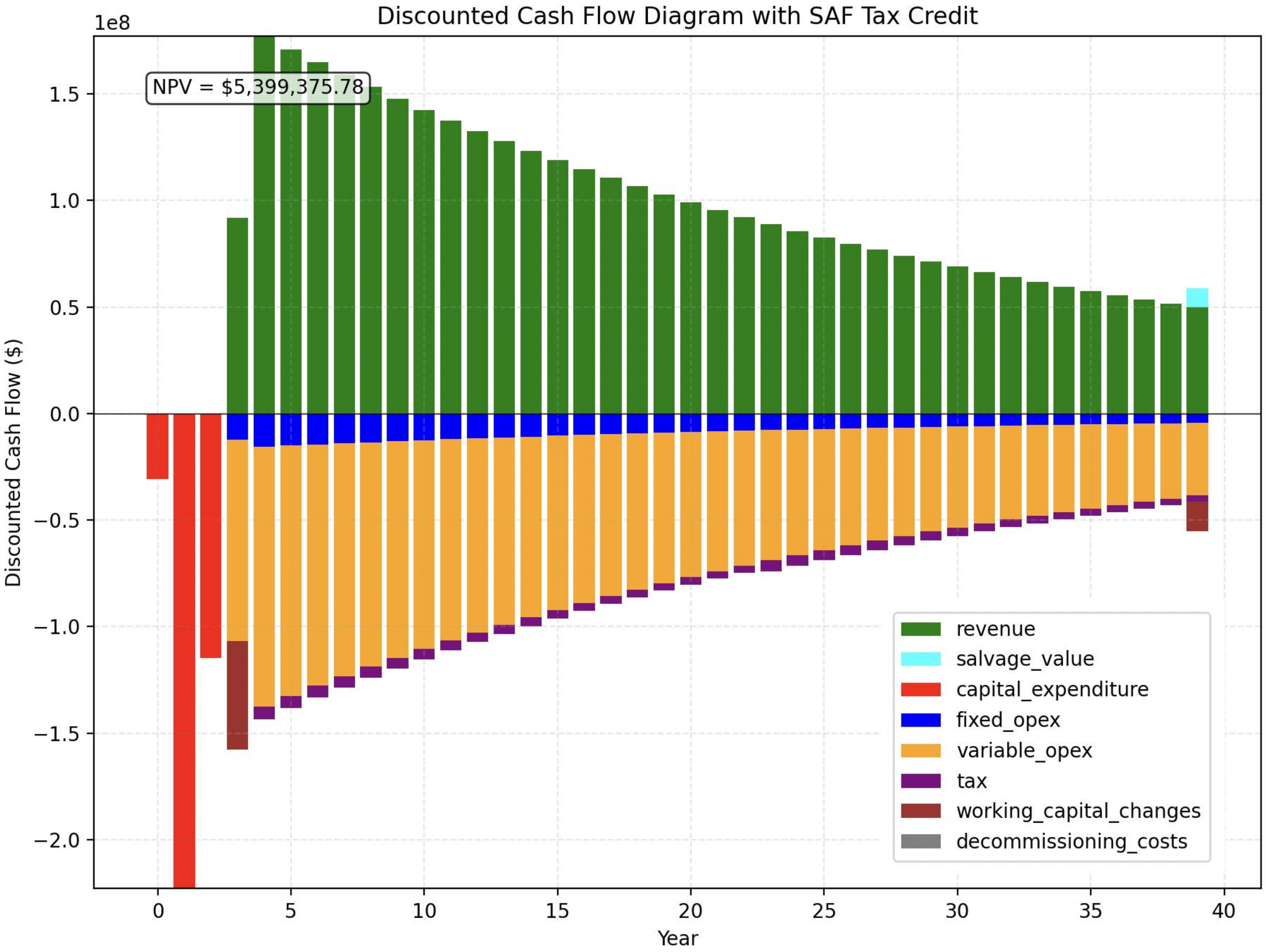
- Even applying the U.S. 40B SAF tax credit, which provides ~$1.75/gal is not enough.
- If sold at market price, the tax credit would **need to increase by ~70%** to reach a breakeven NPV
- ***Importantly, other paths to cost parity exist***, no tax credit is needed to reach a breakeven NPV given:
    - GH2 Cost of $3.00
    - Sales Price of ~$1600 per ton

Achieving a sales price of $1400/ton with 40B. results in positive NPV



- A sales price of $1400 and applying 40B SAF tax credits results in an extremely profitable facility.
  - **NPV: ~+600 million**
- **Securing high-paying offtake is key to achieving project bankability.**

A sales price of $1600/ton and reduced GH2 costs results in positive NPV without extra incentive



- Achieving long-term, sustainable offtake is necessary for project bankability.
- **Current market SAF prices range between $1,100 - $1,700/ton.**
  - Estimated costs sit within this range
  - PtL SAF produces larger emissions reductions than biomass-based SAF.

PtL SAF is not competitive in the near-term but could be an attractive option as costs fall.

- PtL SAF could play a pivotal role in decarbonizing aviation fuels, yet high fuel costs ***prevent immediate adoption***.
- As green hydrogen (and carbon capture costs) fall, ***the economic viability will increase***.
- The reliance on GH2 costs, while hurting short-term project viability, also presents an ***opportunity as a demand-sink for India's growing GH2 sector.***